XVIII. *Report on the beſt Method of proportioning the Exciſe upon Spirituous Liquors. By* Charles Blagden, *M. D. Sec. R. S. and F. A. S.*

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PART I.

On the Experiments.

IN conſequence of an application from Government to Sir Joseph Banks, Bart. Preſident of the Royal Society, for the beſt means of aſcertaining the juſt proportion of duty to be paid by any kind of ſpirituous liquor that ſhould come before the Officers of Exciſe, I was requeſted by that Gentleman to aſſiſt in planning the proper experiments for this purpoſe, and to draw up the Report upon them when they ſhould be finiſhed.

Though various indications of the ſtrength of ſpirituous liquors have been deviſed, applicable in a groſs manner to general uſe, it is well known that no method admits of real accuracy but that of the ſpecific gravity. The weights of an equal bulk of water and pure ſpirit differ from one another by at leaſt a ſixth part of the weight of the former; whence it is obvious, that, when thoſe two fluids are mixed together, the compound muſt have ſome intermediate ſpecific gravity, approaching nearer to that of water or pure ſpirit, as the former or the latter is the more predominant ingredient. Were it not for a certain effect attending the mixture of water and ſpirits, which has been called their mutual penetration, the ſpecific gravity of theſe compoſitions, in a given degree of heat, would be ſimply in the arithmetical proportion of the quantity of each of the fluids entering into them. But whenever different ſubſtances, which have a ſtrong tendency to unite together, are mixed, the reſulting compound is found to occupy leſs ſpace than the ſubſtances forming it held in their ſeparate ſtate; wherefore the ſpecific gravity of ſuch compounds is always greater than would be given by a ſimple caculation from the volume of their ingredients. Though it be a general fact, that ſuch a decreaſe of bulk takes place on the mixture of ſubſtances which have a chemical attraction for each other, yet the quantity of this diminution is different in them all, and, under our preſent ignorance of the intimate compoſition of bodies, can be determined by experiment only. To aſcertain, therefore, the quantity and law of the condenſation reſulting from this mutual penetration of water and ſpirit, was the firſt object to which the following experiments were directed.

All bodies, in general, expand by heat; but the quantity of this expanſion, as well as the law of its progreſſion, are probably not the ſame in any two ſubſtances. In water and ſpirit they are remarkably different. The whole expanſion of pure ſpirit from 30° to 100° of FAHRENHEIT's thermometer, is not leſs than $\frac{1}{25}$th of its whole bulk at 30°; whereas that of water, in the ſame interval, is only $\frac{1}{145}$th of its bulk. The laws of their expanſion are ſtill more different than the quantities. If the expanſion of quickſilver be, as uſual, taken for the ſtandard (our thermometers being conſtructed with that fluid), the expanſion of ſpirit is, indeed, progreſſively increaſing with reſpect to that ſtandard, but not much ſo within the above-mentioned interval; whilſt water kept from freezing to 30°, which may eaſily be done, will abſolutely contract as it is heated for ten or more degrees, that is, to 40° or 42° of the thermometer, and will then begin to expand as its heat is augmented, at firſt ſlowly, and afterwards gradually more rapidly, ſo as to obſerve upon the whole a very increaſing progreſſion. Now, mixtures of theſe two ſubſtances will, as may be ſuppoſed, approach to the leſs or the greater of thoſe progreſſions, according as they are compounded of more ſpirit or more water, whilſt their total expanſion will be greater, according as more ſpirit enters into their compoſition; but the exact quantity of the expanſion, as well as law of the progreſſion, in all of them, can be determined only by trials. Theſe were, therefore, the two other principal objects to be aſcertained by experiment.

The firſt ſtep towards a right performance of the experiments was to procure the two ſubſtances with which they were to be made as pure as poſſible. Diſtilled water is in all caſes ſo nearly alike, that no difficulty occurred with regard to it; but the ſpecific gravity of pure ſpirit, or alcohol, has been given ſo very differently by the authors who have treated of it, that a particular ſet of experiments appeared neceſſary for determining to what degree of ſtrength rectified ſpirits could conveniently be brought. The perſon engaged to make theſe experiments was Dr. DOLLFUSS, an ingenious Swiſs gentleman then in London, who had diſtinguiſhed himſelf by ſeveral publications on chemical ſubjects. Dr. DOLLFUSS, having been furniſhed by Government with ſpirit for the purpoſe, rectified it by repeated and ſlow diſtillations till its ſpecific gravity became ſtationary in this manner of operating: he then added dry cauſtic alkali to it, let it ſtand for a few days, poured off the liquor, and diſtilled it with a ſmall addition of burnt alum, placing the receiver in ice. By this method he obtained a ſpirit whoſe ſpecific gravity was ,8188 at 60° of heat. Perceiving, however, that he could not conveniently get the quantity of ſpirit he wanted lighter than ,82527 at 60°, he fixed upon that ſtrength as a ſtandard, to which he found the above-mentioned lighter ſpirit could be reduced by adding to it a $\frac{27}{1000}$th part of water; and with this ſpirit and diſtilled water he made a ſeries of experiments for determining the ſpecific gravity of different mixtures of theſe fluids in different degrees of heat.

The proceſs followed by Dr. DOLLFUSS is not here given as the beſt poſſible for obtaining pure ſpirit; nor was the reſult of it, in fact, the lighteſt alcohol that has been procured. Some ſpirit has been tried ſince that time, whoſe ſpecific gravity was ,813 at 60°. This was furniſhed by Dr. GEORGE FORDYCE, F. R. S. who ſucceeded in bringing it to that ſtrength chiefly by adding the alkali very hot. Care muſt be taken that none of the cauſtic alkali comes over in the diſtillation. Some alcohol was alſo ſent, for trial, by Mr. LEWIS, an eminent diſtiller in Holborn, whoſe ſpecific gravity, at the ſame temperature, was ,814.

It was with ſpirit rectified from malt-ſpirits that Dr. DOLLFUSS's ſeries of experiments was made; but he tried ſeveral comparative experiments with ſuch as had been rectified from rum and brandy, and found no other difference than might fairly be aſcribed to unavoidable errors.

Upon examining the reſults of Dr. DOLLFUSS's experiments it was perceived, that though the numbers agreed together tolerably well upon the whole, yet in ſome places there was that degree of irregularity in the firſt differences as made it adviſable to repeat ſeveral of the experiments; and Dr. DOLLFUSS leaving England about that time, the buſineſs of this repetition was intruſted to Mr. GILPIN, Clerk of the Royal Society. This gentleman had already taken a part in the buſineſs, by aſſiſting Dr. DOLLFUSS in the former experiments, particularly in the very nice part of weighing the mixtures; and his great ſkill, accuracy, and patience, in conducting experiments, as well as in computations, had on other occaſions been proved to many Members of the Society. One experiment leading on to another, Mr. GILPIN was at length induced to go through the whole ſeries anew; and as the deductions in this Report will be taken chiefly from that laſt ſet of experiments, it is proper here to deſcribe minutely the method obſerved by Mr. GILPIN in his operation. This naturally reſolves itſelf into two parts, the way of making the mixtures, and the way of aſcertaining their ſpecific gravity.

1. The mixtures were made by weight, as the only accurate method of fixing the proportions. In fluids of ſuch very unequal expanſions by heat as water and alcohol, if meaſures had been employed, increaſing or decreaſing in regular proportions to each other, the proportions of the maſſes would have been ſenſibly irregular; now the latter was the object in view, namely, to determine the real quantity of ſpirit in any given mixture, abſtracting the conſideration of its temperature. Beſides, if the proportions had been taken by meaſure, a different mixture ſhould have been made at every different degree of heat. But the principal conſideration was, that with a very nice balance, ſuch as was employed on this occaſion, quantities can be determined to much greater exactneſs by weight, than by any practicable way of meaſurement. The proportions were, there-

fore, always taken by weight. A phial being provided of ſuch a ſize as that it ſhould be nearly full with the mixture, was made perfectly clean and dry, and being counterpoiſed, as much of the pure ſpirit as appeared neceſſary was poured into it. The weight of this ſpirit was then aſcertained, and the weight of diſtilled water, required to make a mixture of the intended proportions, was calculated. This quantity of water was then added, with all the neceſſary care, the laſt portions being put in by means of a well known inſtrument, which is compoſed of a ſmall diſh terminating in a tube drawn to a fine point: the top of the diſh being covered with the thumb, the liquor in it is prevented from running out through the tube by the preſſure of the atmoſphere, but inſtantly begins to iſſue by drops, or a very ſmall ſtream, upon raiſing the thumb. Water being thus introduced into the phial, till it exactly counterpoiſed the weight, which, having been previouſly computed, was put into the oppoſite ſcale, the phial was ſhaken, and then well ſtopped with its glaſs ſtopple, over which leather was tied very tight, to prevent evaporation. No mixture was uſed till it had remained in the phial at leaſt a month, for the full penetration to have taken place; and it was always well ſhaken before it was poured out to have its ſpecific gravity tried.

2. There are two common methods of taking the ſpecific gravity of fluids; one by finding the weight which a ſolid body loſes by being immerſed in them; the other by filling a convenient veſſel with them, and aſcertaining the increaſe of weight it acquires. In both caſes a ſtandard muſt have been previouſly taken, which is uſually diſtilled water; namely, in the firſt method by finding the weight loſt by the ſolid body in the water, and in the ſecond method, the weight of the

veſſel filled with water. The latter was preferred for the following reaſons.

When a ball of glaſs, which is the propereſt kind of ſolid body, is weighed in any ſpirituous or watery fluid, the adheſion of the fluid occaſions ſome inaccuracy, and renders the balance comparatively ſluggiſh. To what degree this effect proceeds is uncertain; but from ſome experiments made by Mr. GILPIN, with that view, it appears to be very ſenſible. Moreover, in this method a large ſurface muſt be expoſed to the air during the operation of weighing, which, eſpecially in the higher temperatures, would give occaſion to ſuch an evaporation as to alter eſſentially the ſtrength of the mixture. It ſeemed alſo, as if the temperature of the fluid under trial could be determined more exactly in the method of filling a veſſel, than in the other: for the fluid cannot well be ſtirred while the ball to be weighed remains immerſed in it; and as ſome time muſt neceſſarily be ſpent in the weighing, the change of heat which takes place during that period will be unequal through the maſs, and may occaſion a ſenſible error. It is true, on the other hand, that, in the method of filling a veſſel, the temperature could not be aſcertained with the utmoſt preciſion, becauſe the neck of the veſſel employed, containing about ten grains, was filled up to the mark with ſpirit not exactly of the ſame temperature, as will be explained preſently; but this error, it is ſuppoſed, would by no means equal the other, and the utmoſt quantity of it may be eſtimated very nearly. Finally, it was much eaſier to bring the fluid to any given temperature when it was in a veſſel to be weighed, than when it was to have a ſolid body weighed in it; becauſe in the former caſe the quantity was ſmaller, and the veſſel containing it more manageable, being readily heated with the hand or warm water, and cooled with cold water: and the very circumſtance, that ſo much of the fluid was not required, proved a material convenience. The particular diſadvantage in the method of weighing in a veſſel, is the difficulty of filling it with extreme accuracy; but when the veſſel is judiciouſly and neatly marked, the error of filling will, with due care, be exceedingly minute. By ſeveral repetitions of the ſame experiments, Mr. Gilpin ſeemed to bring it within the $\frac{1}{15000}$th part of the whole weight.

The above-mentioned conſiderations induced me, as well as the gentlemen employed in the experiments, to give the preference to weighing the fluid itſelf; and that was accordingly the method practiſed both by Dr. Dollfuss and Mr. Gilpin in their operations.

The veſſel choſen as moſt convenient for the purpoſe was a hollow glaſs ball, terminating in a neck of a ſmall bore. That which Dr. Dollfuss uſed held 5800 grains of diſtilled water; but, as our balance was ſo extremely accurate, it was thought expedient, upon Mr. Gilpin's repetition of the experiments, to uſe one of only 2965 grains capacity, as admitting the heat of any fluid contained in it to be more nicely determined. The ball of this veſſel, which may be called the weighing-bottle, meaſured about 2,8 inches in diameter, and was ſpherical, except a ſlight flattening on the part oppoſite to the neck, which ſerved as a bottom for it to ſtand upon. Its neck was formed of a portion of a barometer tube, ,25 of an inch in bore, and about 1½ inch long; it was perfectly cylindrical, and on its outſide, very near the middle of its length, a fine circle or ring was cut round it with a diamond, as the mark to which it was to be filled with the liquor. This mark was made by fixing the bottle in a lathe, and turning it round with great care, in contact with the diamond. The glaſs of this bottle was not very thick; it weighed 916 grains, and, with its ſilver cap, 936.

When the ſpecific gravity of any liquor was to be taken by means of this bottle, the liquor was firſt brought nearly to the required temperature, and then the bottle was filled with it up to the beginning of the neck only, that there might be room for ſhaking it. A very fine and ſenſible thermometer (to be more particularly deſcribed hereafter) was then paſſed through the neck of the bottle into the contained liquor, which ſhewed whether it was above or below the intended temperature. In the former caſe the bottle was brought into colder air, or even plunged for a moment in cold water; the thermometer in the mean time being frequently put into the contained liquor, till it was found to ſink to the right point. In like manner when the liquor was too cold, the bottle was brought into warmer air, immerſed in warm water, or more commonly held between the hands, till upon repeated trials with the thermometer the juſt temperature was found. It will be underſtood, that during the courſe of this heating or cooling, the bottle was very frequently ſhaken between each immerſion of the thermometer; and the top of the neck was kept covered, either with the finger, or a ſilver cap made on purpoſe, as conſtantly as poſſible. Hot water was uſed to raiſe the temperature only in heats of 80° and upwards, inferior heats being obtained by applying the hands to the bottle; when the hot water was employed, the ball of the bottle was plunged into it and again quickly lifted out, with the neceſſary ſhaking interpoſed, as often as was neceſſary for communicating the required heat to the liquor; but care was taken to wipe the bottle dry after each immerſion, before it was ſhaken, leſt any adhering moiſture might by accident get into it. The liquor having by theſe means been brought to the deſired temperature, the next operation was to fill up the bottle exactly to the mark upon the neck, which was done with ſome of the ſame liquor, by means of a glaſs funnel with a very ſmall bore. Mr. GILPIN endeavoured to get that portion of the liquor which was employed for this purpoſe, pretty nearly to the temperature of the liquor contained in the bottle; but as the whole quantity to be added never exceeded ten grains, a difference of ten degrees in the heat of that ſmall quantity, which is more than it ever amounted to, would have occaſioned an error of only $\frac{1}{30}$ of a degree in the temperature of the maſs. Enough of the liquor was put in, to fill the neck rather above the mark, and the ſuperfluous quantity was then abſorbed to great nicety, by bringing into contact with it the fine point of a ſmall roll of blotting paper. As the ſurface of the liquor in the neck would be always concave, the bottom or centre of this concavity was the part made to coincide with the mark round the glaſs: and in viewing it care was taken, that the near and oppoſite ſides of the mark ſhould appear exactly in the ſame line, by which means all parallax was avoided. A ſilver cap, which fitted tight, was then put upon the neck, to prevent evaporation; and the whole apparatus was in that ſtate laid in the ſcale of the balance, to be weighed with all the exactneſs poſſible.

The ſpirit employed by Mr. GILPIN was furniſhed to him by Dr. DOLLFUSS, under whoſe inſpection it had been rectified from rum ſupplied by Government. Its ſpecific gravity, at 60 degrees of heat, was ,82514. It was firſt weighed pure, in the above-mentioned bottle, at every five degrees of heat, from 30 to 100 incluſively. Then mixtures were formed of it and diſtilled water, in every proportion from $\frac{1}{20}$th of the water to equal parts of water and ſpirit; the quantity of water added being ſucceſſively augmented, in the proportion of five grains to one hundred of the ſpirit; and theſe mixtures were alſo weighed in the bottle, like the pure ſpirit, at every 5 degrees of heat. The numbers hence reſulting are delivered in the following table; where the firſt column ſhews the degrees of heat; the ſecond gives the weight of the pure ſpirit contained in the bottle at thoſe different degrees; the third gives the weight of a mixture in the proportions of 100 parts by weight of that ſpirit to 5 of water, and ſo on ſucceſſively till the water and the ſpirit are in equal parts. The bottle itſelf, with its cap, having been previouſly counterpoiſed, theſe numbers are the weights of the liquor contained in it, in grains and hundredths of a grain. They are the mean of three ſeveral experiments at leaſt, as Mr. GILPIN always filled and weighed the bottle over again that number of times, if not oftener. The heat was taken at the even degree, as ſhewn by the thermometer, without any allowance in the firſt inſtance, becauſe the coincidence of the mercury with a diviſion can be perceived more accurately than any fraction can be eſtimated; and the errors of the thermometers, if any, it was ſuppoſed would be leſs upon the grand diviſions of 5 degrees, than in any others. It muſt be obſerved, that Mr. GILPIN uſed the ſame mixture throughout all the different temperatures, heating it up from 30° to 100°; hence ſome ſmall error in its ſtrength may have been occaſioned, in the higher degrees, by more ſpirit evaporating than water; but this, it is believed, muſt have been trifling, and greater inconvenience would probably have reſulted from interpoſing a freſh mixture.

TABLE I.

Weights at the different degrees of temperature.

Heat.	The pure ſpirit.	100 grains of ſpirit to 5 grains. of water.	100 grains of ſpirit to 10 grains of water.	100 grains of ſpirit to 15 grains of water.	100 grains of ſpirit to 20 grains of water.	100 grains of ſpirit to 25 grains of water.	100 grains of ſpirit to 30 grains of water.	100 grains of ſpirit to 35 grains of water.	100 grains of ſpirit to 40 grains of water.	100 grains of ſpirit to 45 grains of water.	100 grains of ſpirit to 50 grains of water.
°	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains	Grains.
30	2487,32	2519,98	2548,59	2573,86	2596,65	2617,24	2636,16	2653,54	2669,64	2684,63	2698,41
35	2480,79	2513,48	2541,96	2567,34	2590,15	2610,80	2629,77	2647,30	2663,48	2678,43	2692 32
40	2474,18	2506,98	2535,52	2560,83	2583,70	2604,50	2623,42	2641,02	2657,35	2672,37	2686,37
45	2467,52	2500,33	2528,90	2554,24	2577,16	2597,99	2617,04	2634,68	2650,96	2666,13	2680,25
50	2460,77	2493,48	2522,10	2547,61	2570,64	2591,50	2610,59	2628,26	2644,68	2659,95	2674,04
55	2453,84	2486,51	2515,30	2540,88	2563,94	2584,79	2604,07	2621,77	2638,25	2653,55	2667,72
60	2446,86	2479,75	2508,60	2534,19	2557,23	2578,22	2597,50	2615,26	2631,82	2647,20	2661,45
65	2440,04	2472,97	2501,87	2527,51	2550,56	2571,48	2590,86	2608,72	2625,41	2640,80	2655,09
70	2433,37	2466,28	2495,00	2520,65	2543,84	2564,89	2584,23	2602,14	2618,89	2634,30	2648,65
75	2426,47	2459,18	2488,03	2513,63	2536,91	2558,14	2577,47	2595,43	2612,20	2627,78	2642,17
80	2419,18	2451,95	2480,83	2506,61	2529,85	2551,10	2570,52	2588,61	2605,32	2621,03	2635,47
85	2412,02	2444,80	2473,68	2499,59	2523,08	2544,41	2563,80	2581,91	2598,76	2614,48	2628,87
90	2404,92	2437,72	2466,64	2492,62	2516,20	2537,57	2556,95	2575,20	2592,17	2607 86	2622,30
95	2397,75	2430,56	2459,51	2485,51	2509,15	2530,51	2549,95	2568,18	2585,12	2601,12	2615,70
100	2390,64	2423,53	2452,63	2478,59	2502,15	2523,59	2543,08	2561,28	2578,37	2594,45	2609,11

Heat.	100 grains of ſpirit to 55 grains of water.	100 grains of ſpirit to 60 grains of water.	100 grains of ſpirit to 65 grains of water.	100 grains of ſpirit to 70 grains of water.	100 grains of ſpirit to 75 grains of water.	100 grains of ſpirit to 80 grains of water.	100 grains of ſpirit to 85 grains of water.	100 grains of ſpirit to 90 grains of water.	100 grains of ſpirit to 95 grains of water.	100 grains of ſpirit to 100 grains of water.
°	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
30	2711,19	2723,00	2733,84	2744,19	2753,67	2762,61	2771,26	2779,21	2786,47	2793,26
35	2705,08	2716,96	2727,78	2738,24	2747,90	2756,97	2765,47	2773,53	2780,75	2787,59
40	2699,09	2711,02	2721,90	2732,45	2742,18	2751,35	2759,85	2767,78	2775,15	2782,06
45	2692,97	2704,82	2715,98	2726,38	2736,21	2745,47	2754,13	2762,03	2769,55	2776,40
50	2686,81	2698,63	2709,92	2720,37	2730,27	2739,52	2748,22	2756,25	2763,67	2770,62
55	2680,57	2692,44	2703,67	2714,27	2724,20	2733,47	2742,25	2750,32	2757,82	2764,72
60	2674,31	2686,16	2697,44	2708,18	2718,26	2727,56	2736,26	2744,32	2751,87	2758,82
65	2667,97	2680,00	2691,22	2701,99	2712,06	2721,47	2730,27	2738,35	2745,93	2752,82
70	2661,67	2673,68	2685,02	2695,66	2705,87	2715,40	2724,22	2732,42	2740,00	2746,88
75	2655,19	2667,32	2678,60	2689,34	2699,57	2709,08	2717,95	2726,25	2733,92	2740,83
80	2648,47	2660,69	2672,02	2682,77	2693,03	2702,57	2711,50	2719,78	2727,49	2734,49
85	2641,85	2654,19	2665,54	2676,40	2686,77	2696,33	2705,37	2713,69	2721,47	2728,60
90	2635,38	2647,61	2659,07	2670,09	2680,60	2690,22	2699,10	2707,44	2715,22	2722,32
95	2628,83	2641,10	2652,56	2663,64	2674,20	2683,79	2692,81	2701,18	2708,91	2716,04
100	2622,22	2634,38	2645,95	2657,14	2667,61	2677,25	2686,36	2694,76	2702,50	2709,75

In order to deduce the ſpecific gravities from the numbers in the preceding table, it was neceſſary to weigh diſtilled water in the ſame veſſel. This Mr. GILPIN did, in the ſame manner as before, at the different degrees of heat; and the reſult of his experiments is delivered in the following table, where the firſt column ſhews the heat, and the ſecond gives the weight of the water, at that temperature, contained in the bottle.

TABLE II.

Weights and ſpecific Gravities of diſtilled Water.

Heat.	Weight of the water.	Specific gravity of the water.
°	Grains.	
30		
35	2967,03	1,00087
40	2967,34	1,00091
45	2967,29	1,00084
50	2966,97	1,00066
55	2966,39	1,00040
60	2965,39	1,00000
65	2964,17	,99952
70	2962,72	,99896
75	2961,03	,99832
80	2959,13	,99762
85	2957,03	,99685
90	2954,80	,99602
95	2952,20	,99507
100	2949,36	,99404

There would be two methods of computing the ſpecific gravity, at the different temperatures, from theſe numbers; one, by taking the weight of the water, at the particular temperature in queſtion, for the ſtandard; and the other by fixing on one certain temperature of the water, for inſtance 60°, to be the ſtandard, with its bulk at which that of the ſpirit at all different degrees ſhall be compared. I have preferred the latter method, though not the moſt uſual, becauſe it ſhews, more readily and ſimply, the progreſſion obſerved in the changes of ſpecific gravity, according to the heat and ſtrength of the mixture. This method, however, rendered it neceſſary to make an allowance for the contraction and expanſion of the bottle uſed for weighing the liquors, according to the deviation of their temperature from 60°, either below or above. To obtain this correction, the expanſion of hollow glaſs was taken from General ROY's experiments in the LXXVth volume of the Philoſophical Tranſactions, as ,0000517 of an inch upon a foot for every degree of heat, whence its effect, in enlarging the capacity of a ſphere, was computed, and the reſulting correction added to the weight of the liquors in heats below 60°, and ſubtracted from it in heats above. On the ſame account a third column is given, in the preceding table, to ſhew the ſpecific gravity of water at the different temperatures, its weight at 60° being taken as the ſtandard.

Another correction alſo became neceſſary, on account of the part of the ſtem of the thermometer which was not immerſed in the liquor. This inſtrument, made by RAMSDEN, had its ball ,22 of an inch in diameter, and its ſtem 13 inches in length. From the ball to the commencement of the ſcale 3,6 inches of the ſtem were bare, and then the ſcale began, which reached from 15 to 110 degrees. The part of it particularly made uſe of in theſe experiments, namely, from 30° to 100°, meaſured 6,82 inches. The ſcale was made of ivory, and carried diviſions to every fifth of a degree, the quarters of which could be readily eſtimated; ſo that the inſtrument could be read off to twentieths of degrees. When the thermometer was immerſed in the weighing-bottle, the liquor reached up nearly to what would have been 0° upon its ſtem; hence, as the heat of the room in which the experiments were made remained about 60°, the correction for the different heat of the quickſilver in the ſtem from that in the ball of the thermometer was calculated according to Mr. CAVENDISH's table, given in the LXVIIth volume of the Philoſophical Tranſactions. Thus the real heat of the fluid in the weighing-bottle being found, an allowance was made to reduce it to the exact degree indicated on the ſcale of the thermometer.

The preciſe ſpecific gravity of the pure ſpirit employed was ,82514; but to avoid an inconvenient fraction it is taken, in conſtructing the table of ſpecific gravities, as ,825 only, a proportionable deduction being made from all the other numbers. Thus the following table gives the true ſpecific gravity, at the different degrees of heat, of a pure rectified ſpirit, whoſe ſpecific gravity at 60° is ,825, together with the ſpecific gravities of different mixtures of it with water, at thoſe different temperatures, as far as equal parts by weight.

TABLE III.

Real ſpecific gravities at the different temperatures.

Heat.	The pure ſpirit.	100 grains of ſpirit to 5 grains of water.	100 grains of ſpirit to 10 grains of water.	100 grains of ſpirit to 15 grains of water.	100 grains of ſpirit to 20 grains of water.	100 grains of ſpirit to 25 grains of water.	100 grains of ſpirit to 30 grains of water.	100 grains of ſpirit to 35 grains of water.	100 grains of ſpirit to 40 grains of water.	100 grains of ſpirit to 45 grains of water.	100 grains of ſpirit to 50 grains of water.
30°	,83899	,85001	,85967	,86819	,87589	,88284	,88922	,89509	,90053	,90558	,91023
35	,83673	,84776	,85737	,86592	,87363	,88061	,88700	,89292	,89839	,90342	,90811
40	,83445	,84551	,85515	,86367	,87140	,87843	,88481	,89074	,89626	,90133	,90605
45	,83215	,84321	,85286	,86140	,86913	,87617	,88260	,88855	,89405	,89916	,90393
50	,82981	,84084	,85051	,85910	,86688	,87392	,88036	,88632	,89187	,89702	,90177
55	,82741	,83843	,84815	,85677	,86455	,87159	,87809	,88406	,88963	,89479	,89957
60	,82500	,83609	,84583	,85445	,86223	,86931	,87582	,88181	,88740	,89259	,89741
65	,82262	,83374	,84350	,85213	,85991	,86698	,87352	,87954	,88518	,89037	,89518
70	,82032	,83142	,84111	,84975	,85758	,86469	,87121	,87725	,88291	,88810	,89294
75	,81792	,82896	,83869	,84731	,85517	,86234	,86886	,87491	,88058	,88585	,89068
80	,81543	,82649	,83623	,84491	,85276	,85993	,86648	,87258	,87822	,88352	,88839
85	,81291	,82396	,83371	,84243	,85036	,85757	,86411	,87021	,87590	,88120	,88605
90	,81044	,82150	,83126	,84001	,84797	,85518	,86172	,86787	,87360	,87889	,88376
95	,80794	,81900	,82877	,83753	,84550	,85272	,85928	,86542	,87114	,87654	,88146
100	,80548	,81657	,82639	,83513	,84308	,85031	,85688	,86302	,86879	,87421	,87915

Heat.	100 grains of ſpirit to 55 grains of water.	100 grains of ſpirit to 60 grains of water.	100 grains of ſpirit to 65 grains of water.	100 grains of ſpirit to 70 grains of water.	100 grains of ſpirit to 75 grains of water.	100 grains of ſpirit to 80 grains of water.	100 grains of ſpirit to 85 grains of water.	100 grains of ſpirit to 90 grains of water.	100 grains of ſpirit to 95 grains of water.	100 grains of ſpirit to 100 grains of water.
30°	,91454	,91853	,92219	,92568	,92888	,93191	,93483	,93751	,93996	,94225
35	,91242	,91644	,92009	,92362	,92687	,92995	,93281	,93553	,93796	,94027
40	,91034	,91438	,91805	,92161	,92489	,92799	,93086	,93353	,93602	,93835
45	,90822	,91222	,91599	,91950	,92281	,92595	,92887	,95153	,93407	,93638
50	,90608	,91007	,91388	,91740	,92075	,92388	,92681	,92952	,93202	,93436
55	,90390	,90791	,91170	,91528	,91863	,92176	,92472	,92744	,92997	,93230
60	,90173	,90570	,90954	,91316	,91656	,91971	,92264	,92536	,92791	,93025
65	,89952	,90359	,90738	,91100	,91440	,91769	,92055	,92328	,92584	,92816
70	,89733	,90136	,90522	,90880	,91225	,91547	,91845	,92121	,92377	,92608
75	,89507	,89916	,90298	,90660	,91005	,91326	,91625	,91909	,92164	,92397
80	,89277	,89690	,90072	,90435	,90780	,91103	,91404	,91683	,91943	,92179
85	,89043	,89460	,89843	,90209	,90558	,90882	,91186	,91465	,91729	,91969
90	,88817	,89230	,89617	,89988	,90342	,90668	,90967	,91248	,91511	,91751
95	,88588	,89003	,89390	,89763	,90119	,90443	,90747	,91029	,91290	,91531
100	,88357	,88769	,89158	,89536	,89889	,90215	,90522	,90805	,91066	,91310

From this table, when the ſpecific gravity of any ſpirituous liquor is aſcertained, it will be eaſy to find the quantity of rectified ſpirit, of the above-mentioned ſtandard, contained in any given quantity of it, either by weight or meaſure. As common arithmetic is competent to furniſh the rules for this purpoſe, it would be ſuperfluous to give them here. All the objects of inquiry relative to this buſineſs ſhould, I think, be reduced to Tables; the firſt of which might exhibit the ſpecific gravities of different mixtures, from one to 100 parts of water, increaſing by one, at every degree of heat from 40 to 80, being the utmoſt limits of temperature that can be wanted in common practice. This table need only be calculated to three places of figures, which will always give the quantity of ſpirit true within a fiftieth part of the whole, and in the moſt uſual degrees of heat within a hundredth; and to this number of figures the areometer, or hydrometer, ſhewing the ſpecific gravities, could be ſuited. A further reaſon for continuing only to three places of figures is, that, accurate as Mr. GILPIN's experiments have been, ſome irregularities are found in the two laſt of the five decimals to which his tables are calculated. The greateſt of theſe irregularities, I think, do not exceed the quantity correſponding to a difference of one-fifth of a degree of heat, and in general they are much leſs. A table might be conſtructed to ſhew what the numbers would probably have been, to the five places of decimals, if there had been no kind of error in the experiments.—Another table ſhould be of the volumes, exhibiting what proportion the ſpirit and water bore to each other by meaſure or bulk, in the different mixtures; whence might be calculated a very uſeful table of Diminutions, to ſhew when a given weight, or volume, of a certain ſpirit and water are mixed together, how much their bulk would be diminiſhed; or, what is called by the diſtillers the *concentration*. From ſuch a table the diſtiller could learn, what quantity of water he muſt mix with ſpirit of a given ſtrength, in order to reduce it to proof ſpirit, or any other ſtrength; and likewiſe what quantity of proof ſpirit, or ſpirit of any other ſtrength, he may obtain, by adding water to ſpirit of a given ſtrength; both circumſtances very neceſſary to be known in the trade, and which ſome of the ſliding rulers now in uſe profeſs to point out.

It may appear odd, that no mention has been made till now of *proof ſpirit*, the ſtandard to which moſt of the regulations of the exciſe have hitherto been referred. The reaſons for not adopting this ſtandard are: firſt, that the ſtrength of ſpirit to be called proof is a mere arbitrary point, and by no means ſo exactly determined as could be wiſhed; and ſecondly, that it ſeemed moſt convenient to take for the ſtandard the higheſt ſtrength of ſpirit uſually found in commerce, and beyond which it cannot be rectified without a proceſs of ſome expence, ſo that all the other degrees of ſtrength might be reckoned one way, without the intervention of a middle point, inducing the neceſſity of denominating ſome *above* and others *under*. If, however, Government ſhould find it expedient to preſerve the reference to proof ſpirit, from the tables given in this Report others may be conſtructed, in which all the old terms of over and under proof ſhould be retained, and have a preciſe meaning, as ſoon as the ſtrength to be called proof ſhall be finally ſettled. By the Act of 2 Geo. III. it is ordered, that the gallon of brandy or ſpirits of the ſtrength of one to ſix under proof, ſhall be taken and reckoned at 7 *lb.* 13 *oz.*, which is underſtood by the trade to mean at 55° of heat. Hence, taking the weight of a gallon of water at the ſame heat to be 8 *lb.* 5,66 &c. *oz.* *, the ſpecific gravity of this diluted ſpirit will be found ,9335 at 60° †; whence, by a computation founded on the tables in this Report, the ſpecific gravity of proof ſpirit will come out ,916. But the rulers of correction belonging to Dicas's and Quin's hydrometers give the ſpecific gravity of proof ſpirits about ,922 at 55°, equivalent to ,920 at 60°. The former, ,916, correſponds to a mixture of 100 parts of ſpirit with 62 by meaſure, or 75 by weight, of water; and the latter, ,920, to a mixture of 100 parts of ſpirit and 66 by meaſure, or 80 by weight, of water. The difference is conſiderable; but the firſt is undoubtedly moſt conformable to the exiſting Acts of Parliament. If, therefore, it be thought right to preſerve the term proof-ſpirit in our Exciſe Laws, it may be underſtood to mean ſpirit, whoſe ſpecific gravity is ,916, and which is compoſed of 100 parts of rectified ſpirit at ,825, and 62 parts of water by meaſure, or 75 by weight; the whole at 60 degrees of heat.

I have choſen this point of the thermometer, 60°, in preference to 55°, becauſe it is much the moſt ſuitable for experiments, being the temperature at which a room feels pleaſant, and in which any operation, however ſlow and tedious, can be executed without the uneaſy ſenſation of cold: for this reaſon it has been adopted by many Engliſh philoſophers. In the table formerly recommended, from 40 to 80 degrees of the thermometer, it will be the middle temperature.

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* Probably 8 *lb.* 5,72 *oz.* is nearer.

† This ſpecific gravity indicates a mixture of 107 grains of water with 100 of ſpirit, and conſequently is below Mr. Gilpin's preſent Tables, which go only to equal parts.

The ſpecific gravity of ,825 having been fixed upon as the ſtandard of rectified ſpirit in our tables, Mr. GILPIN was deſired to aſcertain by experiment what proportion of water would be neceſſary, to reduce the lighteſt alcohol in his poſſeſſion to that ſtandard. This was ſome alcohol, already mentioned, which Mr. LEWIS had furniſhed; and its ſpecific gravity being ,814196 at 60°, 3000 grains of it mixed with 135 grains of diſtilled water formed a compound, whoſe ſpecific gravity was ,825153; that is, in round numbers, 100 grains of alcohol at ,814 with 4,5 grains of water, form our ſtandard of ſpirit at ,825.

Perhaps ſome perſons may object to the preceding experiments, on account of the ſmall quantities mixed and weighed. Undoubtedly experiments on a large ſcale have ſome advantages; but theſe in general depend more on the coarſeneſs of tools, and clumſineſs of operators, than on the nature of the operations. If inſtruments be exceedingly exact, and the experimenter equal to the taſk of uſing them properly, I believe the errors upon moderate quantities will be quite as ſmall in proportion as upon large; and in this particular inſtance, where the greateſt ſource of error lay in the determination of the heat, the ſmaller quantities had in that reſpect an evident advantage, it being much eaſier to bring ſix ounces of a liquor to an uniform temperature than ſo many gallons. One of our moſt eſſential inſtruments, namely, the balance, was ſo much ſuperior in nicety to any thing that could be wanted in theſe experiments, that error in weighing muſt be thrown entirely out of the queſtion. It was conſtructed by Mr. RAMSDEN; and ſome account, though very imperfect, of its admirable mechaniſm, as well as of its extreme ſenſibility, even when loaded with conſiderable weights, has been given in the XXXIIId volume of the *Journal de Phyſique.*

I muſt not conclude this part of the Report without obſerving, that as the experiments were made with pure ſpirit and water, if any extraneous ſubſtances are contained in the liquor to be tried, the ſpecific gravity in the tables will not give exactly the proportions of water and ſpirit in it. The ſubſtances likely to be found in ſpirituous liquors, where no fraud is ſuſpected, are, eſſential oils, ſometimes empyreumatic, mucilaginous or extractive matter, and perhaps ſome ſaccharine matter. The effect of theſe, in the courſe of trade, ſeems to be hardly ſuch as would be worth the cognizance of the exciſe, nor could it eaſily be reduced to any certain rules. Eſſential and empyreumatic oils are nearly of the ſame ſpecific gravity as ſpirit, in general rather lighter, and therefore, notwithſtanding the mutual penetration, will probably make little change in the ſpecific gravity of any ſpirituous liquor in which they are diſſolved. The other ſubſtances are all heavier than ſpirit; the ſpecific gravity of common gum being 1,482, and of ſugar 1,606, according to the tables of M. Brisson. The effect of them therefore will be to make ſpirituous liquors appear leſs ſtrong than they really are. An idea was once entertained of endeavouring to determine this matter with ſome preciſion; and accordingly Dr. Dollfuss evaporated 1000 grains of brandy, and the ſame quantity of rum, to dryneſs; the former left a reſiduum of 40 grains, the latter only of 8½ grains. The 40 grains of reſiduum from the brandy, diſſolved again in a mixture of 100 of ſpirit with 50 of water, increaſed its ſpecific gravity ,00041; hence the effect of this extraneous matter upon the ſpecific gravity of the brandy containing it would be to increaſe the fifth decimal by 6 nearly, equal to what would indicate, in the above-mentioned mixture, about one-ſeventh of a grain of water more than the truth, to 100 of ſpirit: a quantity much too minute for the conſideration of Government.

PART II.

On Hydrometers.

THE readieſt way of aſcertaining ſpecific gravities, and undoubtedly the moſt convenient for public buſineſs, is by hydrometers; and, I conceive, thoſe of the ſimpleſt conſtruction to be beſt upon the whole, eſpecially if more accurate means are kept at hand, to be reſorted to in caſe of diſputes. An hydrometer of glaſs would be the moſt certain; but whether it be of that ſubſtance, or of metal, it ſhould conſiſt of a ball, or rather bulb, ſo poiſed as that a certain part ſhould be always downmoſt in the liquor, and having a ſtem riſing from it on the oppoſite part, which would conſequently keep upright in uſing the inſtrument. On the ſize of this ſtem, the ſenſibility of the hydrometer chiefly depends. In the old areometers the ſtem was made ſo large, that the volume of water diſplaced between its leaſt and greateſt immerſions was equal to the whole difference of ſpecific gravity between water and alcohol, or perhaps more; whence its ſcale of diviſions muſt be very ſmall, and could not give the ſpecific gravity with much accuracy. To remedy this defect, weights were introduced, by means of which the ſtem could be made ſmaller, each weight affording a new commencement of its ſcale; ſo that the ſize of the diviſions on a given length of ſtem was doubled, tripled, quadrupled, &c. according as one, two, three, or more weights were employed, the diameter of the ſtem being leſſened in the ſubduplicate proportion of the increaſed length of the diviſions. Of late this principle ſeems to have been carried to exceſs; the number of weights adapted to ſome hydrometers being ſo great as to prove very inconvenient in practice. A mean between the two methods would certainly be beſt, which might be ſuited to our tables in the following manner.

It is propoſed to determine the ſpecific gravity to three places of decimals, water being taken as unity: the whole compaſs of numbers, therefore, from rectified ſpirit to water, at 60 degrees of heat, would be the difference between ,825 and 1,000, that is, 175; call it 220 to include the lighteſt ſpirit and heavieſt water, at all the common temperatures. Of theſe diviſions the ſtem might give every twenty, and then ten weights would be ſufficient for the whole 220. By making the ſtem carry twenty diviſions, an inconvenience much complained of, that of ſhifting the weights, would in great meaſure be avoided; becauſe a perſon converſant in ſuch buſineſs would ſeldom err to that extent in judging of the ſtrength of his ſpirit previous to trial; and yet the ſtem would not need to be ſo large, or the diviſions ſo ſmall, as to preclude the deſired accuracy. In conformity to this arrangement it would be proper, that the weights adapted to the hydrometer ſhould be marked with the numbers of the ſpecific gravity, zero on the top of its ſtem, without a weight, being ſuppoſed to mean 800, and 20 at the bottom of the ſtem to ſignify 820, which number the firſt weight would carry; the ſucceſſive weights would be marked 840, 860, &c.; and the diviſion on the ſtem cut by the fluid under trial would be a number to be always added to the number marked upon the weight, the ſum of the two ſhewing the true ſpecific gravity. The weights ſhould unqueſtionably be made to apply on the top of the ſtem, ſo as never to come into contact with the liquor; and in uſing the hydrometer its ſtem ſhould always be preſſed down lower than the point at which it will ultimately reſt, that by being wetted it may occaſion no reſiſtance to the fluid. The inſtrument itſelf ſhould be of as regular a ſhape, and with as few inequalities and protuberances, as poſſible, that all unneceſſary obſtruction to its motions may be avoided.

As it is not probable but diſputes will ſometimes ariſe, I think it would be adviſable, that ſome of the principal exciſe offices ſhould be provided with a good pair of ſcales, and a weighing-bottle properly marked, the quantity of whoſe contents of diſtilled water at 60° had been previouſly determined. By filling this bottle up to the mark with the ſpirit in queſtion, and dividing its increaſe of weight by the given weight of water required to fill it, the ſpecific gravity of the ſpirit would, I think, be better aſcertained, even under the management of a common operator, than by the moſt dexterous uſe of the hydrometer.

The ſimpleſt and moſt equitable method of levying the duty on ſpirituous liquors would be, to conſider rectified ſpirit as the true and only exciſable matter. On this principle, all ſuch liquors would pay exactly according to the quantity of rectified ſpirit they contain; ſo that when a caſk, for inſtance, of any ſpirits was preſented to the revenue officer, his buſineſs would be to determine from the quantity, ſpecific gravity, and temperature, of the liquor, how many gallons, or pounds, of rectified ſpirit enter into its compoſition; each of which gallons, or pounds, ſhould be charged a certain ſum. The complicated regulations attending the adaption of the duties to different degrees of ſtrength would thus be avoided; and it is believed, that many frauds might be prevented, which artful perſons have now an opportunity of practiſing, by altering the ſtrength of their ſpirit in a variety of ways. From the tables already recommended, it would be eaſy to deduce this quantity of rectified ſpirit, either by weight or meaſure, in any given quantity of a ſpirituous liquor; or other tables might be conſtructed which ſhould ſhew it at once by inſpection.

If, however, it be thought by Government moſt expedient not to make any eſſential change in the preſent manner of collecting this article of the revenue, I would at leaſt recommend, that the ſpecific gravity ſhould be ſubſtituted for the relation to proof ſpirit. Thus, inſtead of ordering ſo much duty *per* gallon to be paid by ſpirits one to ſix under proof, it may be enacted, that the ſame ſum ſhall be paid by ſpirit of ,9335 ſpecific gravity, or, not to be too preciſe, by ſpirit from ,930 to ,935, and ſo on for any other degrees of ſtrength; a certain temperature, ſuppoſe 60°, being always underſtood to be meant when ſpecific gravity is mentioned in an Act of Parliament.

The duties to be laid according to either of theſe methods may readily be adjuſted or equalized to thoſe paid at preſent, as far as the latter can be determined from the Act of 2 George III. referred to above, or by any of the inſtruments now in uſe.

It will give me very ſincere pleaſure if the preceding experiment and remarks ſhould tend to advance the proſperity of this country, by introducing a more juſt and advantageous mode of collection into ſo material a branch of the revenue.

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